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Only:

FMRI and PET Demonstrate Sustained Blood Oxygenation and Flow Enhancement During Extended Visual Stimulation Durations

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INTRODUCTION:

Characterization of activation - induced changes in blood flow and oxygenation across time scales is one avenue by which neuronal, metabolic, and hemodynamic relationships may be more fully understood. Prior studies (1) have suggested that local blood oxygenation returns from an initially elevated level to baseline level after about 15 minutes of continuous stimulation. Possible reasons for this observation include either a) decreased neuronal firing with habituation or fatigue or b) an increase in oxidative metabolic rate over time. If the first reason applies, both oxygenation and flow should return to resting levels. If the second reason applies, then oxygenation should decrease but flow should remain elevated.

To test these hypotheses, both blood oxygenation - sensitive (gradient-echo, T2*-weighted) *and* flow - sensitive (2) (inversion recovery, T1-weighted) images were collected during extended duration visual stimulation. Also, using flow measurements obtained by positron emission tomography (PET), habituation effects in primary visual and somatosensory cortex were assessed.

METHODS:

MRI: Five subjects were studied. Flow sensitive (inversion recovery EPI: TI = 1000ms, TR = 3000ms, TE=20ms: spin-echo) and blood oxygenation sensitive (gradient-echo EPI: TR = 3000ms, TE = 40ms) time course series were obtained using a 1.5 T GE Signa scanner retrofitted with an ANMR resonant gradient system. Voxel volume was 3.125 mm x 3.125 mm x 15 mm. Motion correction (3), performed to reduce signal drift related to subject movement, improved signal stability in several experimental runs. Visual stimulation was: 10 Hz full field black and white alternating checkerboard. The timing was: 1 min.off, 1 min.on, 1 min.off, 20 min.on, 1 min.off, 1 min.on, 1 min.off.

PET : Seven and nine subjects were used in the visual stimulation and vibrotactile studies respectively. Cerebral blood flow was measured 40 seconds after bolus intravenous injections of ^{15}O-labeled water at 10 minute intervals during 50 minutes of either continuous 8 Hz full field alternating red and black checkerboard stimulation or vibrotactile stimulation.

RESULTS:

Figures 1 and 2 show averaged, from activated visual cortex of 5 subjects, oxygenation-sensitive and flow-sensitive time course series respectively. No subject demonstrated a significant decrease in flow or oxygenation during the 20 minute stimulation period. A post-stimulation undershoot was also observed with the T2*-weighted sequence and not the T1-weighted sequence.

Figure 3 shows averaged PET measurements, across all subjects. With visual stimulation, the activation-induced flow change did not decrease significantly. With vibrotactile stimulation, the flow change did decrease significantly over time. These results demonstrate that the degree of habituation may vary depending on the stimulus and activated region.

CONCLUSIONS:

Blood flow and oxygenation in V1 remain elevated during extended stimulation. These studies agree with preliminary studies suggesting stable levels of oxidative metabolic rate, and oxygen extraction fraction in V1 during extended stimulation times (4,5). Reasons for the differences between the presented results and those of (1) may include differences in pulse sequence parameters and/or differences in the type of visual stimulation used. Our visual stimulus may be: a) causing less habituation or neuronal fatigue and/or b) selectively activating neurons that do not increase as much in oxidative metabolic rate. Ongoing studies are being performed clarify these issues.

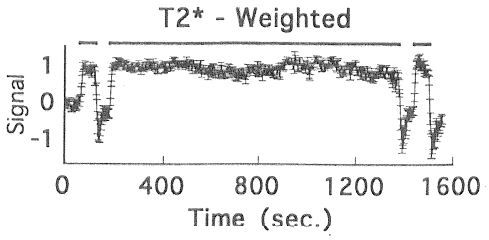

Figure 1: Averaged oxygenation - sensitive MR signal. GE-EPI: TR=3000ms. TE=40ms.

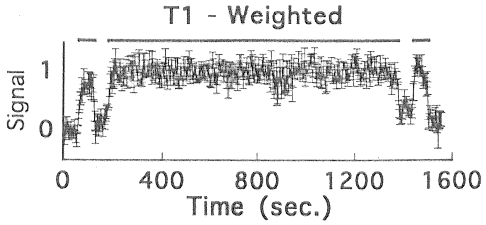

Figure 2: Averaged flow - sensitive MR signal. IR-EPI: TI=1000ms, TR=3000ms, TE=20ms: spin-echo.

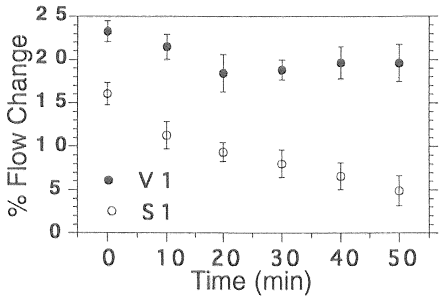

Figure 3: Flow change in V1 and S1 over 50 minutes continual stimulation obtained using ^{15}O - labeled water injections at 10 minute intervals. A significant flow decrease is observed in S1 but not in V1, demonstrating that extended duration flow responses can vary depending on the stimuli used and cortical regions activated.

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